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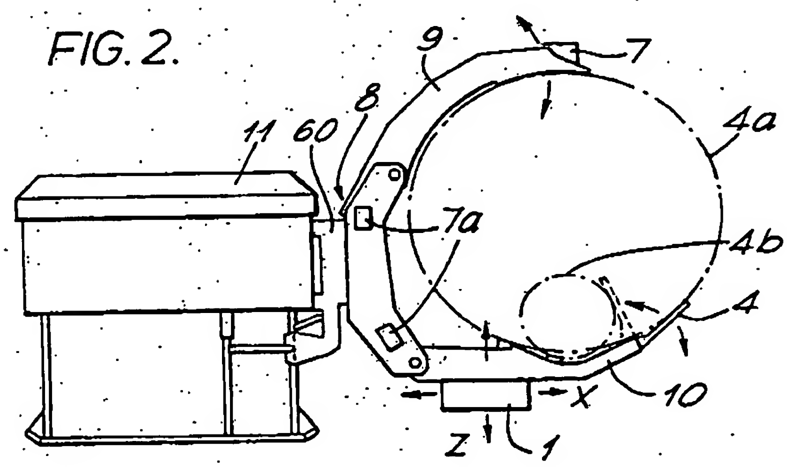
(54) Detecting matter in hollow undersea structures

(57) Apparatus for detecting presence and/or quantity of liquid or solid matter contained within the interior of a hollow structural member comprising a claw member having upper and lower jaws 9, 10 either or both of which can pivot such that the spacing between jaws in a vertical plane is variable, a gamma ray source 1 on one jaw and a detector 7 arranged to provide gamma detection data on the other jaw. The source and/or detector are capable of displacement in a plane which is perpendicular to said vertical plane, whereby in use a plurality of hollow members (4a, 4b) of different external diameters can be inserted between the detector and source such that detection of gamma radiation can occur across said diameter.

The apparatus may be mounted on a remotely operated undersea vehicle 11 and used to test and detect flooding in offshore structures such as oil rigs and undersea pipelines. A marine growth removal device may be provided. The "vertical" axis between the claws may be rotated through ±90° for use on hollow members at any angle.

FIG. 2.



The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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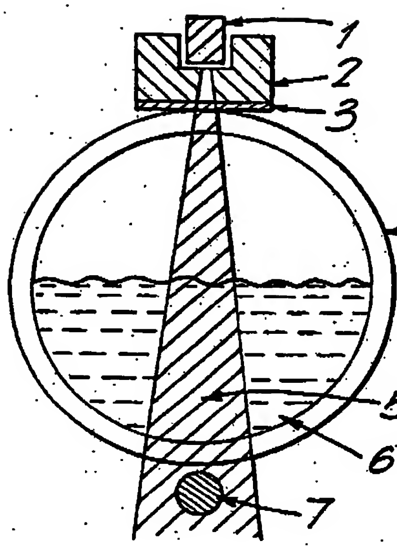


FIG. 1.

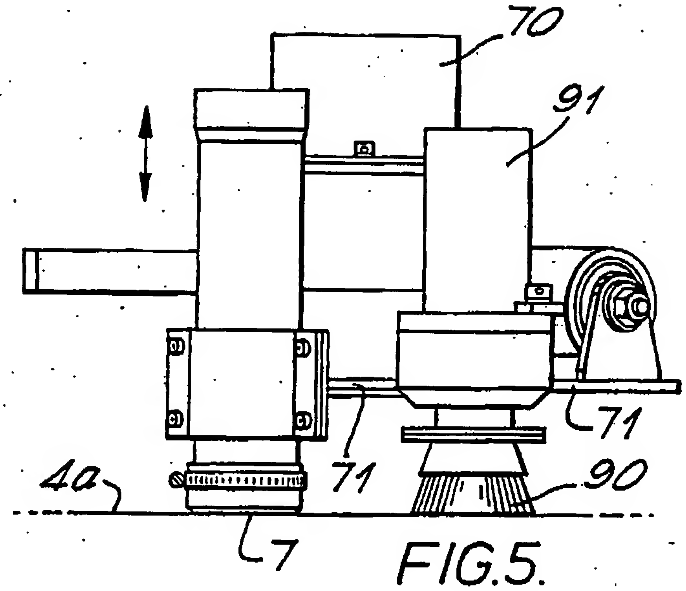
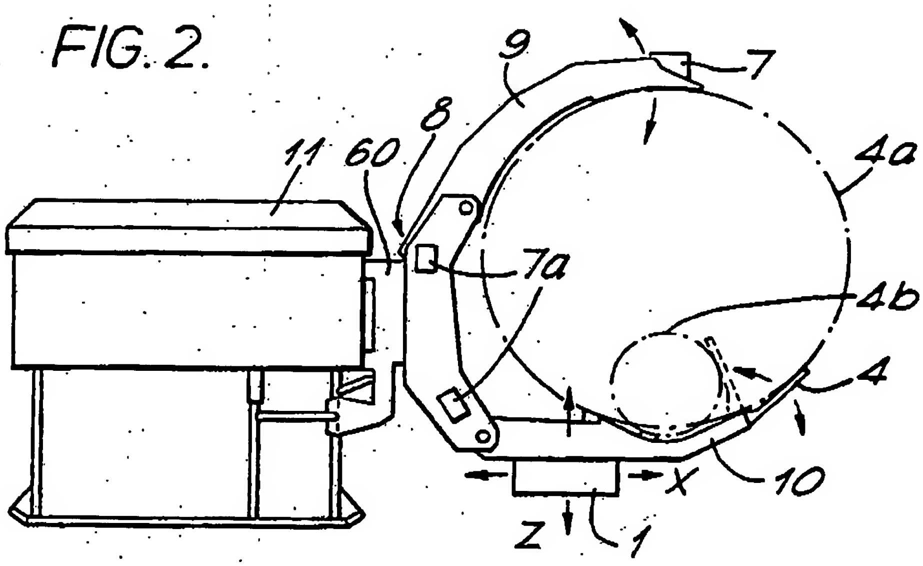


FIG.5.

FIG. 2.



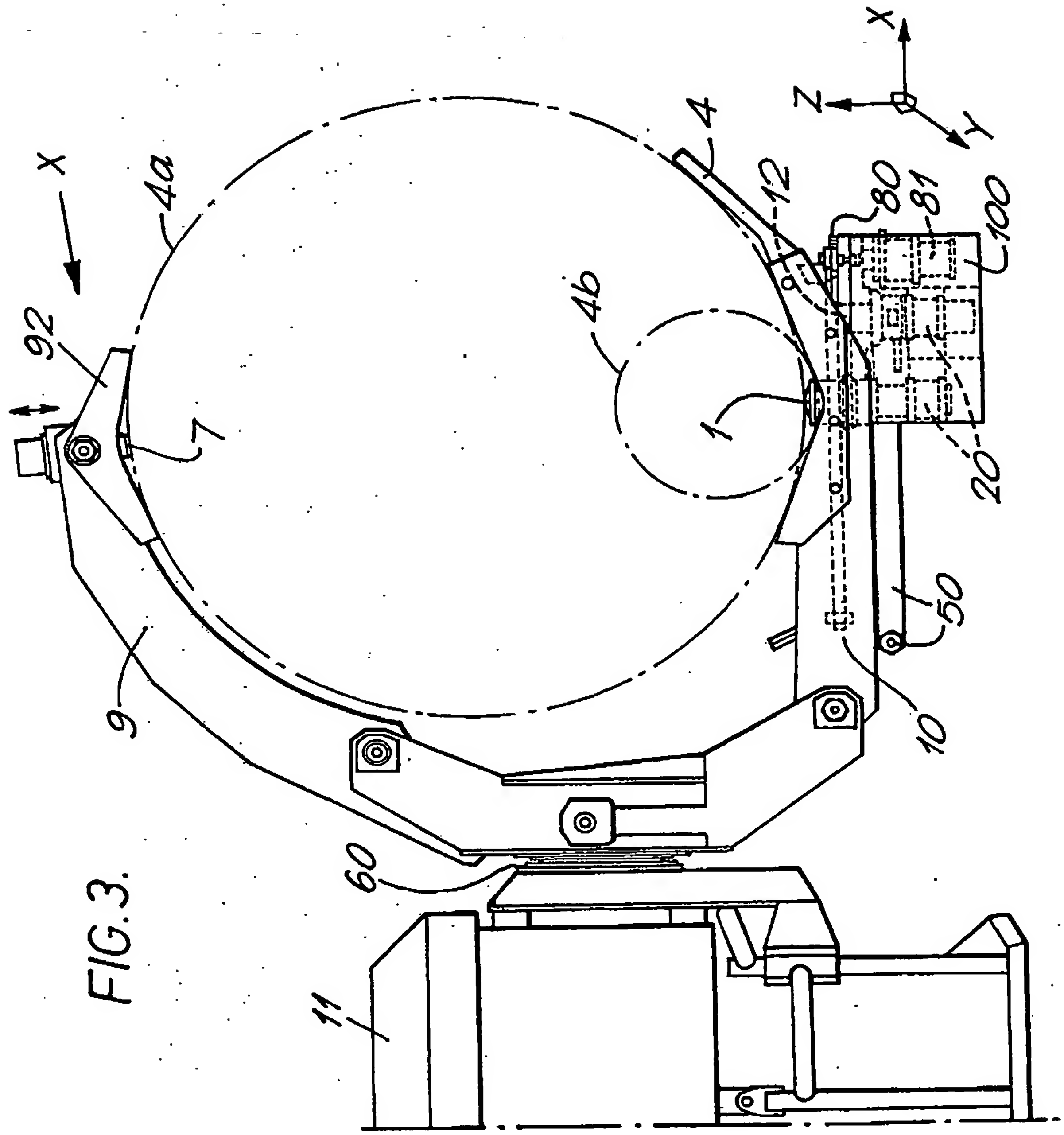


FIG.3.

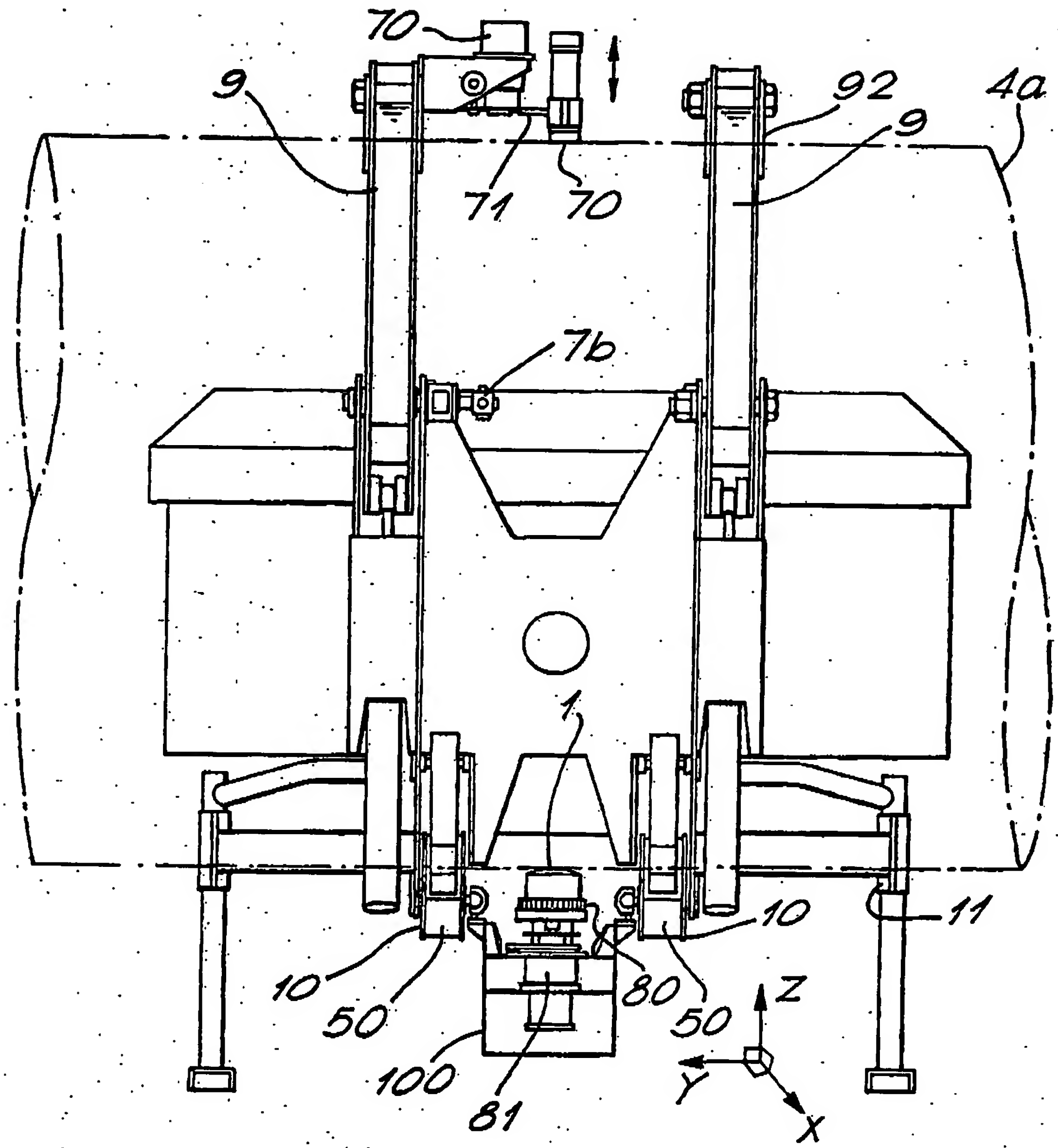


FIG. 4.

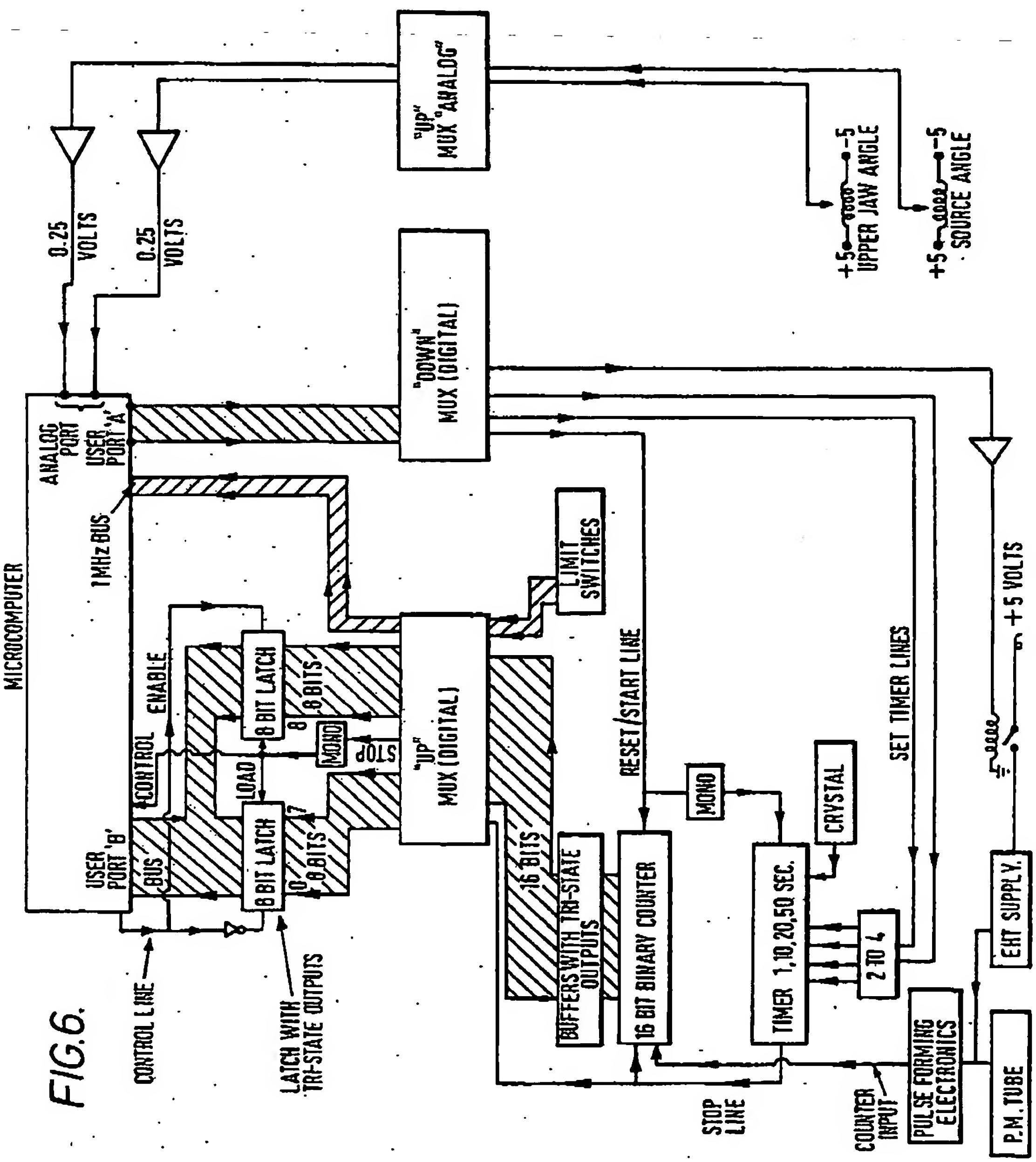

MICROCOMPUTER
ANALOG PORT
USER PORT 'A'
USER PORT 'B'
1MHz BUS
CONTROL
ENABLE
BUS
LOAD
8 BIT LATCH
8 BIT LATCH
8 BITS
8 BITS
MONO
STOP
"UP" MUX (DIGITAL)
"DOWN" MUX (DIGITAL)
"UP" MUX "ANALOG"
0.25 VOLTS
0.25 VOLTS
+5
-5
UPPER JAW ANGLE
SOURCE ANGLE
LIMIT SWITCHES
16 BITS
BUFFERS WITH TRI-STATE OUTPUTS
16 BIT BINARY COUNTER
RESET/START LINE
MONO
CRYSTAL
TIMER 1,10,20,50 SEC.
2 TO 4
SET TIMER LINES
EHT SUPPLY.
+5 VOLTS
PULSE FORMING ELECTRONICS
P.M. TUBE
COUNTER INPUT
STOP LINE
CONTROL LINE
LATCH WITH TRI-STATE OUTPUTS

FIG.6.

TITLE

40089/wsf

Detection Apparatus and Method

This invention is concerned with an apparatus and method for detecting non-gaseous matter in hollow members e.g. as employed on offshore structures. It is more particularly concerned with apparatus and methods for detecting water or solid objects within the interior of a hollow structural member by non-destructive testing.

There is a need to ascertain whether certain undersea hollow structural members contain water, or other liquid, and to obtain fairly accurate quantitative analysis of contained water to assess level of flooding. Thus the invention has principal application in the field of faultfinding on offshore structures such as oil rigs and the like but may also be used for non-destructive testing of such hollow tubular members as pipelines.

Two principal conventional techniques for detecting water in such members are already known. An ultrasonic system relies on transmitting sound through a steel/water interface. When such interface is altered or damaged by corrosion or includes significant quantities of scale or sludge deposited on the interior surface, the ultrasound cannot penetrate through the interface. Penetration

failure results in readings which are indistinguishable from an empty member control. Therefore this known system has limited application and gives unreliable results.

A neutron back-scattering system is also known in which neutrons are generated within the water present in a flooded or partially-flooded undersea member. Neutron generation is however slow resulting in a correspondingly slow count rate even in completely flooded undersea members. Undersea structural members having only minor flooding may provide a virtually negligible count rate. This known system is therefore an unreliable way of determining the flooding within an undersea member on a quantitative basis, more so if the quantitative basis to be determined is small. Additionally neutron back-scattering systems require source to be positioned adjacent the counter for detecting neutron back-scatter. This leads to problems of isolation which can result in spurious readings. It is from a consideration of these known techniques that has led to the development of the present invention.

The invention provides in one aspect apparatus for detecting presence and/or quantity of liquid or solid matter contained within the interior of a hollow structural member comprising a claw member having upper

and lower jaws either or both of which can pivot such that the spacing between jaws in a vertical plane is variable, a gamma ray source on one jaw and a detector therefor on the other jaw, the source and/or detector being capable of displacement in a plane perpendicular to said vertical plane, whereby in use a plurality of hollow members of different external diameters can be inserted between the detector and source whereby the source can be directed at the detector across a diameter of the member.

In a further aspect the invention provides a method of detecting presence and/or quantity of liquid or solid matter contained within a hollow structural member by passing gamma rays from a source at a first external location on the member through the member and detecting gamma rays which have passed through the member and any liquid or solid matter if present at a detector located at a second external location of the member, the spacing between source and detector in a vertical plane being variable and the positioning of detector and/or source being variable in a plane which is perpendicular to said vertical plane.

The present apparatus may be used on members at almost any required angle. To achieve this the present apparatus can be affixed to a remote operated vehicle such that the claw means can rotate through the range

plus 90° to minus 90° relative to the remote operated vehicle. It is preferred for the gamma ray source to be a collimated Cobalt-60 source which is most preferably mounted to be movable within at least two but more preferably three mutually perpendicular planes such as by mounting it (or alternatively the scanner) on an X,X,Z - manipulator. This may have associated electrical feed back means to ensure the gamma ray beam can always be pointed directly at the detector, irrespective of the size or shape of member being tested within the claw mechanism.

The apparatus may employ a specific interface and data transmission system adapted for use with a PIONEER type remote operated vehicle as supplied by Subsea Offshore, Ltd.

As an integral part of the apparatus there may be included at least one wall thickness measuring device such as a known ultrasonic such unit.

The apparatus and method may be adapted for use on offshore structures, pipelines and the like and may be operable manually by a diver or in association with a remote operated vehicle (ROV). It is preferred that structural members to be tested for liquid or solid matter are cylindrical although the apparatus and method may be applied to non-cylindrical members which are

elongate and hollow.

Both jaws may be pivotally connected to the claw mechanism. The detector may be in a fixed position in relation to the jaw on which it is located and the gamma ray source may be variably locatable on its respective jaw. One of the jaws may include a pivotable clamping finger. It is preferred that the mechanism for securing or clamping the jaws around pipes of different external diameters includes means for determining the external diameter of a tubular member to be tested, means for determining the wall thickness of a tubular member to be tested, and/or means for removing marine growth which may accumulate on the exterior surface.

In respect of the method aspect it is preferred that the method is applied to a quantitative determination of water flooding. The emitting and detector positions may be respectively variable but still capable of use along a diameter of the tubular member being tested. The gamma ray count may be derived from a scintillation counter and the count may be displayed on an operator screen remote from the pipe being tested. The count may be manually converted to flooding level or the count may be further computed into supplementary quantitative data manually or by computer programme. This further processing into

quantitative data may involve calibration techniques which take account of factors including diameter, material and wall thickness.

The invention is based on using the variable attenuation to a radioactive gamma ray beam caused by different physical properties of materials which may be found within hollow tubular members. This variable attenuation may be used in assessing the presence of and quantity of material located within the interior thereof. The invention is thus based on the use of this known phenomena. The present invention offers a distinct improvement over the known ultrasonic technique in that gamma rays are capable of passing through corrosion, scale and sludge. The present invention also provides an improvement over the known neutron back-scattering technique because it has been established that gamma ray beams are attenuated as an exponential function of water depth. The present apparatus and method can therefore be very sensitive even in members having minimum flooding and can provide an unambiguous reading. The apparatus and method rely upon detection of attenuation rather than back-scatter and the capability to display diametrical position of source and counter can provide an inherently more

reliable system of detection.

The apparatus may be used by a diver, without connection a a remote operated vehicle.

In order that the invention may be further illustrated and readily carried into effect embodiments thereof will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates in principle the present method of determination,

Figure 2 illustrates in cross-section one form of apparatus according to the invention,

Figure 3 is a more detailed view of Figure 2 showing one form of source and other features within a movable carriage,

Figure 4 is an end elevation of Figure 3,

Figure 5 is one arrangement of photomultiplier-scanner with associated marine growth removal means, and

Figure 6 is a block diagram of one suitable computer system for analysing and interpreting scanning results.

Referring firstly to Figure 1 of the drawings a gamma ray source 1, for example cobalt 60 is housed within a collimator 2 conveniently constructed of lead and having an aperture through which gamma rays may pass

into the interior of the hollow member 4a. The collimator is associated with a shutter 3 for controlling exposures of gamma rays. Gamma rays pass from the source through the collimator and into the interior of the hollow structural member 4a as a collimated beam 5. This passes initially through the wall of the member, which may be a metal pipe of known or evaluated wall thickness, then through the gaseous medium above the water and then into the water 6, passing through the opposite side to a scintillation counter 7. The gamma rays are attenuated by the water 6, the amount of attenuation varying with the path length of the beam in water. The scintillation counter provides a reading of beam intensity.

Referring to Figure 2 of the accompanying drawings, this illustrates apparatus suitable for determining the presence and/or quantity of liquid or solid matter in a hollow tube. This apparatus may be used to carry out the principles of the method shown in Figure 1. The mechanism 8 for clamping around external parts of the tube comprises a pair of pivotally mounted jaws 9,10, whose spacing is variable and controlled by means of a remote operated vehicle (ROV) 11. A gamma ray source and collimator 1 are located on the lower jaw 10 in such a way as to be manoeuvrable both laterally and

longitudinally within X and Z planes with respect to the jaw 10. This is indicated by arrows on item 1. The scintillation counter is optionally provided with a marine growth removal system (not shown). The source and collimator are similarly optionally provided with a marine growth removal system. The source is preferably located in a movable carriage on the lower jaw 10 which can further carry a wall thickness meter. The lower jaw 10 includes a pivotal clamping finger 4 which is movable to accommodate tubular members of comparatively smaller external diameters. The lower jaw and its associated finger serve to hold the source and collimator 1 in a position which is, or can be, diametrically opposed to the scintillation counter 7. Figure 2 shows a pair of tubular members 4a, 4b having different external diameters which may be subjected to the present method.

The diameter of the tubular member under investigation may be gauged by its geometry and a pair of linear voltage displacement transducers (LVDT's) 7a on the claw mechanism 8 and which indirectly measure the angle included by the jaws 9,10. A rotary actuator 6 associated with the ROV 11 allows the claw mechanism to be clamped at virtually any angle required.

The apparatus shown in Figure 2 may accommodate hollow structural members of substantially different

external diameters. In addition to the capacity of the apparatus to be used as a flooded member detector on hollow members having non-circular cross-sections, i.e. non-cylindrical tubular members, the apparatus may also be useful in locating objects which are present therein. The radiation count can be used for detecting the presence of solid objects in similar fashion to the technique for determining the presence of water.

Referring to Figures 3 and 4 of the drawings there are shown respectively a more detailed view of the arrangement shown in Figure 2, including a view (Figure 4) in elevation. The upper jaw 9 comprises a pair of spaced apart jaw members and the lower jaw 10 further comprises a pair of spaced apart jaw members. One of the upper jaw members 9 has a clamp member to engage a part of the external circumference of a pipe to be tested. The other upper jaw member carries the detector 7. The detector can be a scintillation counter or a photomultiplier. It is arranged to be displaceable in at least the plane shown by arrows in Figure 4. This is achieved by mounting the detector 7 upon a mounting plate 71 whose height can be varied by a manipulator 70. Thus by varying the relative displacement of scanner or detector 7 the part can be made to contact the outer circumference of the hollow member 4a under test. Further

details of the arrangement will be described subsequently with reference to Figure 5.

The arrangement of Figures 3 and 4 show a carriage assembly 1 which houses a gamma ray source and collimator 1 together with a wall thickness meter 12 which may be a known ultrasonic probe, and a marine growth removal means comprising a rotary brush 80 and associated motor therefor 81. The gamma ray source 1 is located upon a movable manipulator 20. The manipulator can move the scanner in the mutually perpendicular X, Y and Z planes depicted. The wall thickness meter 12 is further mounted upon another manipulator 20 capable of similar movement. The drive means 81 for rotary brush 80 may also be movable within at least vertical plane Z if required. It is movable along the horizontal Z plane as it is affixed to the movable carriage. The whole carriage 100 comprising these units is itself movable within the X horizontal plane indicated. The carriage is conveniently supported upon projecting rails shown in Figure 4 and driven by drive assembly 50 shown in Figure 3. Accordingly the gamma ray source 1 can always be effectively directed towards the scanner to enable readings and measurements to be made across the diameters of hollow cylindrical members of different sizes. In the position shown in Figure 3 the probe can contact the

external circumference of the larger diameter hollow member 4a. It can be recessed to accommodate the smaller diameter hollow member 4b. For major variations in external diameter the jaw members 9 and 10 will themselves be separated or closed together by means of the ROV 11. The rotary actuator 60 allows the member to be clamped at any angle from plus to minus 90° relative to the ROV.

The marine growth removal system comprising the rotary brush 80 and associated drive means 81 may be positioned against the external circumference of the hollow member to be tested to effect cleaning prior to taking any readings. The wall thickness meter 12 may be brought into use prior to taking radiation attenuation readings and thereby used in any subsequent calculations for analysing the depth of liquid that may be contained within the hollow member 4a or 4b.

In place of the linear voltage transducers used in connection with the Figure 2 arrangement, the embodiment of Figures 3 and 4 uses one rotary indicator assembly 7b to indicate the relative orientation between jaws to assist in determining level of flooding.

Referring to Figure 5 of the drawings, there is shown one form of gamma radiation detector in association with marine growth removal means. The view comprises a

partial end elevation on the upper jaw in the direction of arrow X shown in Figure 3. The detector 7 and marine growth removal means comprising a rotary brush 90 and associated drive means 91 located upon a swivel plate 71. The swivel plate 71 is connected to a manipulator 70 as also shown in Figure 4. Accordingly the swivel plate and thereby both detector and marine growth removal means can be raised or lowered to contact the external circumference of the hollow member 4a being tested. In use, the detector 7 can be swivelled out of contact with the external circumference of the hollow member 4a whereby the rotary brush may be brought into operation to clean any marine growth on the exterior circumference prior to testing.

All the various control means required for manipulators, carriage drive means and the like may be provided through the intermediary of the ROV 11.

As shown by Figure 6, the block diagram gives details of one microprocessor based system for converting the scintillation counts into a clear definition of flooding levels. A computer programme may be devised by means readily available to a computer programmer to compute a flooding level based on sensing input data corresponding to (a) attenuation itself based on gamma ray count (b), wall thickness (being the thickness which

may be obtained by a wall thickness meter used on the jaws of the apparatus), and (c) the diameter of the tubular member (which may be ascertained by a reading of relative jaw orientation through items 7a or 7b). The computer may be programmed to operate in accordance with the basic equation:

$$C = PC \times \exp(-alphaw \times D) \times \exp(-alphas \times 2WT) \times 1/R^2$$

where

C	=	predicted count rate
PC	=	calibration constant
alphaw	=	attenuation coefficient of water
alphas	=	attenuation coefficient of steel
D	=	depth of water in pipe
WT	=	wall thickness of pipe
R	=	distance between source and detector.

Thus D can be analysed and interpreted.

In short summary, it can be seen that the present apparatus and method allow for qualitative and quantitative investigations into liquid levels or solid matter located within a hollow structural member, principally in underwater applications. Variable attenuation of the gamma ray beam caused by the presence of solid or liquid material is used for qualitative and quantitative evaluations. The wall thickness (and the wall material itself) may

be used as factors considered in the quantitative analysis of data. The ROV attachment where required may provide a reliable way of fixing the apparatus to the structural member undergoing test and of providing a fixed geometry for calculating material and quantity thereof and this may contribute to reducing operator fatigue. The computer programme which may be used in subsequent evaluation of scintillation count may embody a mathematical description of the pipe allowing the number of counts recorded by the detector to be converted into e.g. a water flooding level or other quantity of contained material by using a calibration procedure. The present apparatus and method can provide a reliable method of measuring quantity of contained material being dependent only on the physical gamma ray attenuation properties of the contained material.

CLAIMS

1. Apparatus for detecting presence and/or quantity of liquid or solid matter contained within the interior of a hollow structural member comprising a claw member having upper and lower jaws either or both of which can pivot such that the spacing between jaws in a vertical plane is variable, a gamma ray source on one jaw and a detector therefor on the other jaw, the source and/or detector being capable of displacement in a plane perpendicular to said vertical plane, whereby in use a plurality of hollow members of different external diameters can be inserted between the detector and source whereby the source can be directed at the detector across a diameter of the member.

2. Apparatus as claimed in Claim 1 wherein the source and/or detector is/are further capable of displacement in two or more planes perpendicular to said vertical plane.

3. Apparatus as claimed in Claim 1 or 2 wherein the source and/or detector is/are further capable of displacement in said vertical plane or in a plane parallel therewith and independently of any displacement of the upper and/or lower jaws.

4. Apparatus as claimed in any preceding claim wherein the source and/or detector are provided with marine growth removal means.

5. Apparatus as claimed in any preceding claim wherein the lower and/or upper jaw have hollow member thickness evaluation means.

6. Apparatus as claimed in any preceding claim including rotary indication means for providing data as to relative jaw orientation.

7. Apparatus as claimed in any preceding claim wherein the source and/or detector is/are affixed to a manipulator.

8. Apparatus as claimed in any one of Claims 4 to 7 wherein source and optionally the marine growth removal means are housed in a movable carriage.

9. Apparatus as claimed in Claim 8 in which said carriage can be displaced in a plane perpendicular to said vertical plane and along the length of the lower jaw.

10. Apparatus as claimed in any one of Claims 4 to 9 wherein the detector is attached to marine growth removal means on a swivel assembly which is capable of movement in a horizontal plane perpendicular to said vertical plane.

11. Apparatus for detecting presence and/or quantity of liquid or solid matter substantially as herein described with reference to Figure 2 of the accompanying drawings.

12. Apparatus for detecting presence and/or quantity of liquid or solid matter substantially as herein described with reference to and as illustrated in any one of Figures 3, 4 or 5 of the accompanying drawings.

13. A remote operated vehicle which is attached to an apparatus as claimed in any preceding claim.

14. A method of detecting presence and/or quantity of liquid or solid matter contained within a hollow structural member by passing gamma rays from a source at a first external location on the member through the member and detecting gamma rays which have passed through the member and any liquid or solid matter if present at a detector located at a second external location of the

member, the spacing between source and detector in a vertical plane being variable and the positioning of detector and/or source being variable in a plane which is perpendicular to said vertical plane.

15. A method as claimed in Claim 14 using apparatus as defined in any one of Claims 1 to 13.

16. A method of detecting presence and/or quantity of liquid or solid matter substantially as herein described, with reference to Figure 2 of the accompanying drawings.

17. A method of detecting presence and/or quantity of liquid or solid matter substantially as herein described with reference to Figures 3, 4 or 5 of the accompanying drawings.

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